Partial Desilting of Irrigation Tank to Enrich Recharge Capacity

D. Allwin and M. Ganesan

***Abstract*—The hydrology of Groundwater movement depends upon the physical and chemical characteristics of both soil and water. These features must be measured and related to subsurface storage space and water dynamics, so as to decide the feasibility of a site for recharge and to select suitable methods and systems of recharge. So that water may be efficiently stored underground and then used independently or conjunctively with releases from surface storage reservoirs. In irrigation tanks, heavy siltation is the main limiting factor for percolation efficiency. The study of geology or soil characteristics in the tank bed for the infiltration recharging system is rather more important. At the same time Hydraulic conductivity is also very important parameter. Therefore, estimates of initial infiltration rates are must for estimating hydraulic conductivities of infiltration system in irrigation tanks. In this study, it has been planned to assess the recharge behavior of the tank bed in order to locate the highly permeable zone for desilting by conducting geophysical survey to demarcate the location for infiltration test. The results obtained from the infiltration test were correlated with the soil properties. From the analysis, the recharge characteristics of the tank bed were assessed.**

***Index Terms*—Desilting, Geophysical Survey, Hydraulic Conductivity, Infiltration Test.**

I. Introduction

Water is the main life supporting ingredient of the world. Its availability varies with time and space. Water and land are the two important assets of any country and proper utilization of them can bring prosperity to the living society. Water is the only renewable resource available in limited quantities and is not available throughout the year in the same quantities. The study of the flow of fluids through porous media is important in water resources engineering. The mode of occurrence of groundwater depends largely upon the type of formation, and hence depends upon the geology of the area. The movement of groundwater is dependent upon the factors that are permeability and hydraulic gradient. Infiltration is the process of downward water entry into the soil. Telis (2001) have carried out a study to estimate the infiltration rate of saturated soils. Infiltration rates are subject to significant change with soil use, management and time [6].When water is initially applied to the soil surface, the infiltration rate is equal to the rate of application. Infiltration of water increases water storage in the soil profile and groundwater recharge and reduces erosion.

II. Partial Desilting

The purpose of the tank is to store the water for irrigation and domestic use. Hence, the conservation of water is very essential. One of the major implications of the large water spread area is that of the heavy evaporation losses. Further a sizable area is under water, which may be otherwise put to other uses if it is possible. Therefore, volume is the criteria, but not the area. It is possible to store the same quantum of water over a smaller area provided the bed is deeper than before. Deepening the bed will result in the water level to go below the sill level of the deepest sluice. The idea here is to deepen the bed and to reduce the water spread area. Deepening the bed may also make the tank to function as a percolation pond in which case the ground water may be recharged which would amount to an effective way of water conservation.

III. Need for the Study

Tanks are extremely important for an agricultural country like India. The purpose for which tanks have been developed over the years has been lost because of silting up of the tank due to various natural man made activities. Tanks remain the main source of ground water recharge in its surroundings and this can be felt from the wells in the catchments and the command area. The study, of tank bed characteristics assumes extremely important with regard to its recharge potential. No research has been done so far in studying the tank bed characteristics. Hence a study of tank bed recharge characteristics for effective desilting assumes considerable importance.

IV. Study Area

The Tanks chosen for the study are (i) Ponpadi tank, (ii) Sengulam tank. The Ponpadi tank situated about 0.6 km from Ponpadi village in Thiruthani Taluk of Thiruvallur District. The latitude and longitude of the tank are 13°13´58” N and 79°35´59” E respectively, with an altitude of 99 m above mean sea level. The Sengulam tank is situated at the end of Sengulam village which is at a distance of 15 Km from Virudhunagar town of Madurai District. The latitude and longitude of the tank are 9º 38’ 33” and 77º 49’ 47” respectively, with an altitude of 125.578 m above mean sea level. The Study area details and Hydraulic particulars of the Sengulam and Ponpadi Tanks are presented in the Table I.

Manuscript published July 31, 2016

D Allwin, Noorul Islam University, Kanyakumari, India. (e-mail: winniu@ymail.com)

Madhavi Ganesan, Centre for Water Resources, College of Engineering Guindy, Anna University Chennai, Tamilnadu, India. (e-mail: madhaviganesan@gmail.com)

TABLE I: STUDY AREA DETAILS AND HYDRAULIC PARTICULARS

Tank Name	Ponpadi	Sengulam
Type of Tank	Rain-fed	Rain-fed
District	Thiruvallur	Madurai
Latitude	13° 09' 20"	9° 38' 32.45"
Longitude	79° 32' 20"	77° 49' 47.24"
Full Reservoir Level	95.2 m	121.110 m
Mean Water Level	95.6 m	121.710 m
No. of Sluice	1	3
Ayacut	145.35 Ha	50 Ha
Capacity of Tank	1.61 M m^3	0.295 M m^3
Catchment area	11.75 km^2	4.60 km^2
Average Rainfall	1004.51 mm	772.04 mm
Southwest	464.49 mm	162.49 mm
Northeast	441.31 mm	409.37 mm
Winter	20.91 mm	41.27 mm
Summer	77.80 mm	158.9 mm
Dependable Rainfall	850 mm	604.1mm
Water availability	1.01 m^3 / m^2	0.6 m^3 / m^2

Terra Very Low Frequency (T-VLF) Survey

Terra Very Low Frequency (T-VLF) survey is an electromagnetic survey used for delineation of the permeable zone within the tank bed. Riberiro and Nunes (1999), has carried out a study to delineate Permeable zone by geophysical data [4]. T-VLF survey was carried out at two study places, namely Ponpadi tank and Sengulam tank. At Ponpadi tank, T-VLF survey was started at 25 m from the tank bund to a distance of 220 m and at an interval of 10m. Line1, line2, and line3 are the three stretches carried out for T-VLF survey of the ponpadi tank bed as shown in fig. 1. The total area surveyed was 1291m^2 and resistivity

contours were drawn to find out the highly permeable zone. Fig. 1 shows the longitudinal variation of apparent resistivity at the Ponpadi tank bed. Similarly the survey was conducted at Sengulam tank bed from sluice 2 to Sluice 3 to a distance of 700 m. At every 10 m interval apparent resistivity was noted. Fig. 2 shows the longitudinal variation of apparent resistivity at Sengulam tank bed. Line1, line2, line3, line4 and line 5 are the five stretches carried out for T-VLF survey of the sengulam tank bed as shown in fig.2. The apparent resistivity between 1- 2 ohm-m is considered as the permeable zone for conducting the infiltration test. By drawing Iso-resistivity map the Geology of the area is decided.

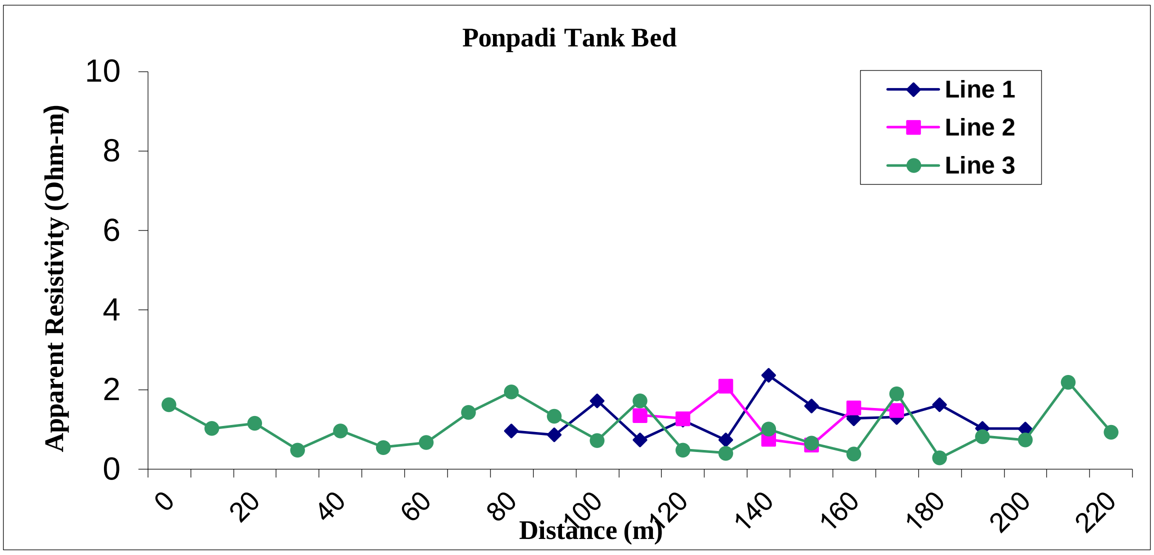

Fig. 1. Apparent Resistivity of Ponpadi Tank Bed

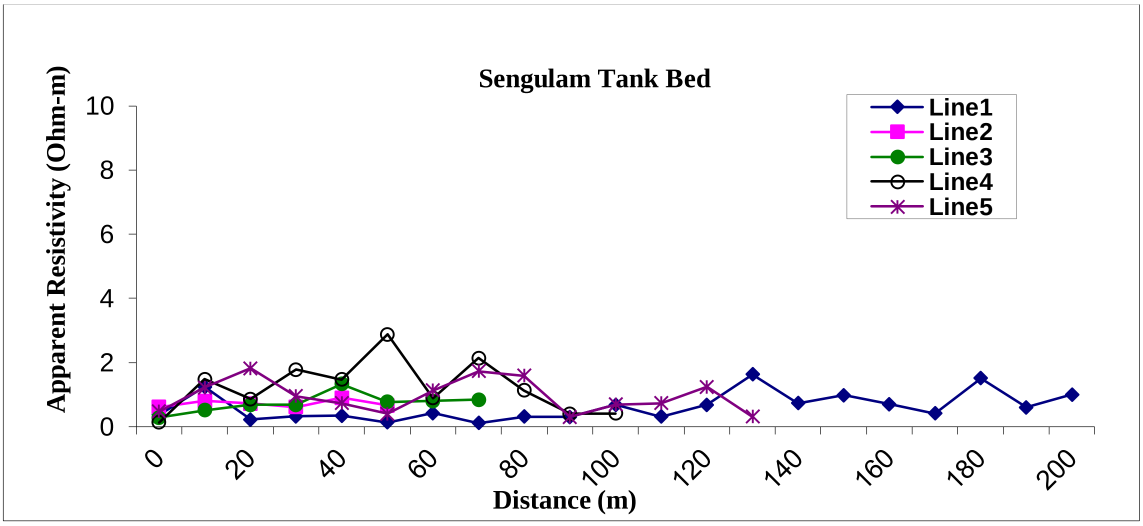

Fig. 2. Apparent Resistivity of Sengulam Tank Bed

ISO-Resistivity Mapping

The data of the T-VLF survey was used for the preparation of the iso-resistivity map of the Ponpadi and Sengulam tank bed. Iso-resistivity map display the lateral variation in the subsurface geology of the area. The iso-resistivity map details the distribution of resistance to a depth of five meters. Fig. 3 shows the iso-resistivity map for Ponpadi tank where the apparent resistivity lies between 0.84 Ohm-meter to 1.78 Ohm-meter. From the Iso-resistivity map and the observed litholog of nearby wells, the geology of the area is decided in which less than one Ohm-meter indicates highly weathered and saturated genesis and greater than one Ohm-meter (1 Ohm-meter to 1.78 Ohm-meter) indicates the sandy layer up to a depth of five meter below the tank bed. Hence the area of the permeable zone in the Ponpadi tank for desilting is calculated as 1910 m^2. Similarly for Sengulam tank the Geology of the area is decided from the Iso-resistivity map and the observed litholog of nearby wells. Fig. 4 shows the iso-resistivity map for Sengulam tank where the apparent resistivity lies between 0.04 Ohm-meter to 2.92 Ohm-meter in which greater than two Ohm-meter indicates Rock out crop (Hard rock) less than one Ohm-meter indicates unweathered granite with water filled joints and between one to two Ohm-meter indicates the sandy layer up to a depth of five meter below the tank bed. The area of the permeable zone at Sengulam tank for desilting is calculated as 2353 m^2. Hence the apparent resistivity between 1- 2 ohm-meters is considered as the permeable zone for conducting the infiltration test.

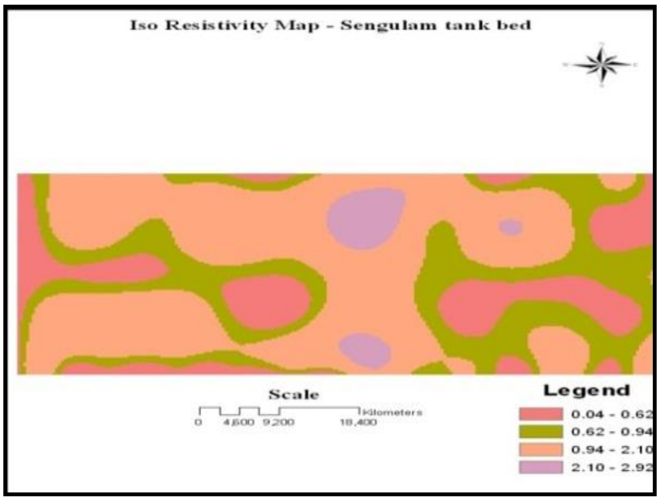

Fig. 3. Iso-Resistivity Map of Ponpadi Tank Bed

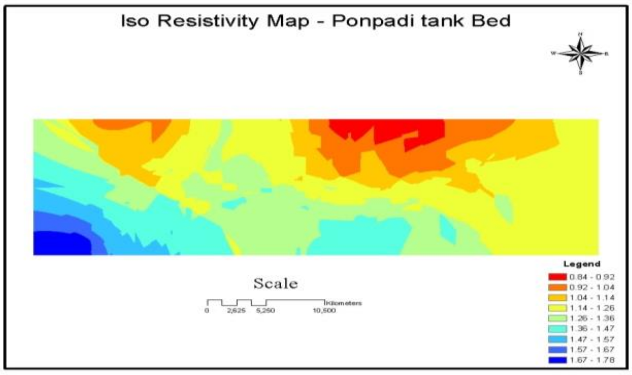

Fig. 4. Iso-Resistivity Map of Sengulam Tank Bed

V. Infiltration Rate Analysis of Tank Bed

Infiltration is the process by which water enters the soil. It separates water into two major hydrologic components, namely the surface runoff and the subsurface recharge. Double ring infiltrometer is used to measure the infiltration rate as shown in fig. 5. Infiltration rate usually shows a sharp decline with time from the start of the application of water [2].The constant rate approached after a sufficiently large time is referred to as the Steady infiltration rate. Infiltration Capacity is the maximum rate of water is absorbed by the soil. Rainwater infiltration significantly decreases with increasing basin slope and reducing the slope length [5]. Based on the very low frequency survey, infiltration test was done with the help of double ring infiltrometer at high permeable zone of Ponpadi tank bed. The test was carried out at various locations of surface, 50cm, 100 cm and 150 cm depths below ground level in order to determine the depth for which the desilting has to be carried out. Similarly, in Sengulam tank bed infiltration test was done with the help of double ring infiltrometer at Surface, 50 cm and 100 cm depths below ground level.

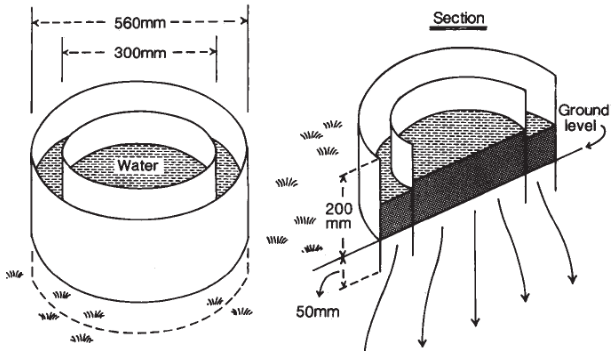

Fig. 5. Double Ring Infiltrometer

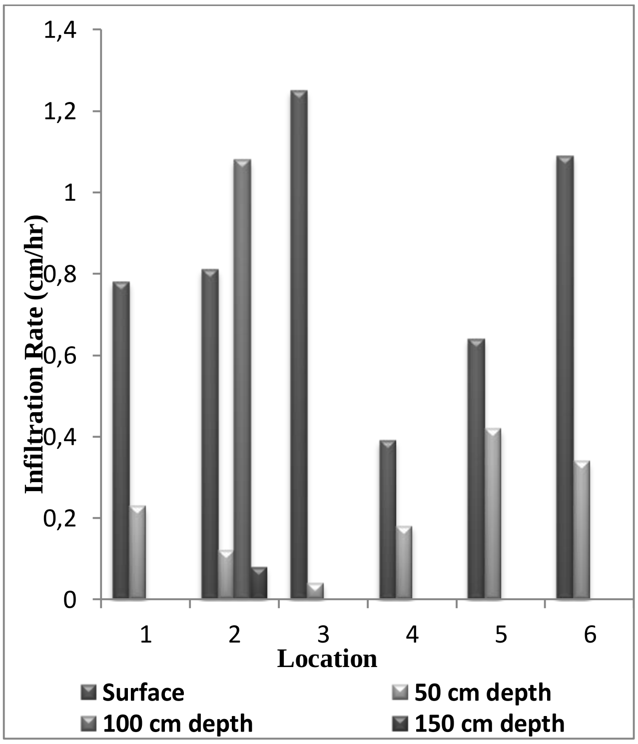

Fig. 6. Infiltration Rate of Ponpadi Tank Bed

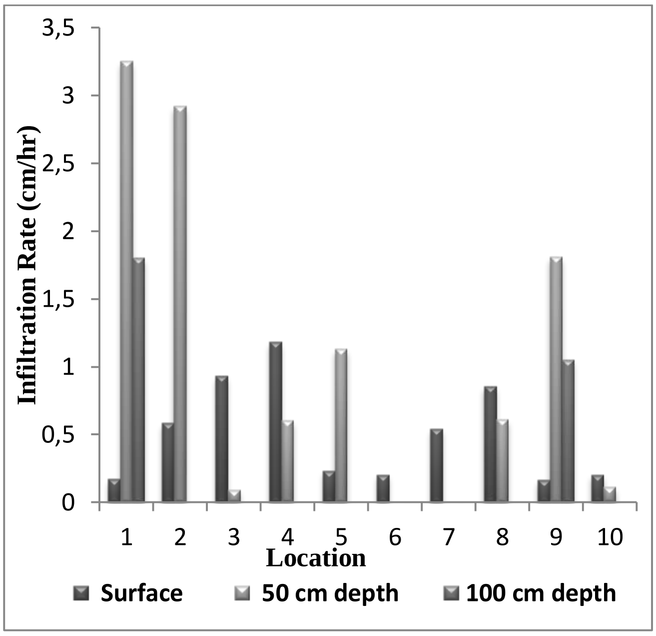

Fig. 7. Infiltration Rate of Sengulam Tank Bed

In Ponpadi tank bed average infiltration rate was 8.2 mm/hr at surface, 2.2 mm/hr at50 cm depth and 10.8 mm/hr at 100 cm depth as shown in Fig. 6. Catchment area of the Ponpadi tank is surrounded by hill. Hence, during monsoon period surface flow takes place directly from the hill towards the tank making the coarser sand particles to settle in the tank. In addition it is also found that a change in the soil profile below 90 cm that extending upto 115 to 150 cm depth is observed. In Sengulam tank bed it is observed that the infiltration rate was, 5.1 mm/hr at surface and 15.0 mm/hr at50 cm depth as shown in Fig. 7.Below 100cm depth infiltration tests were not possible due to rock formations. The catchment area of the Sengulam tank is agriculture land and as a result there is a movement of black cotton soil into the tank.

VI. Soil Texture Analysis

Soil texture is a soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil. Soil texture classification is based on the fractions of soil separates present in a soil. The jar test is used to estimate the relative volume of the major soil constituents such as sand, silt, and clay [1]. Three kilograms of soil sample were collected in a polythene bag from each location on both the tank bed where the infiltration test was done. Soil texture analysis was carried out by the use of the quartz glass jar as shown in fig. 8. The percent sand is the depth of the sand divided by the depth of the total soil. The percent silt is the depth of the silt divided by the depth of the total soil. The percent clay is 100 minus the percent sand plus silt. In Ponpadi tank the existence of silty clay at surface, clay at 50 cm to 100 cm depth and sandy clay below 100 cm depth were observed. In Sengulam tank, surface layer is dominated by clay and subsurface is dominated by sandy loam and clay loam.

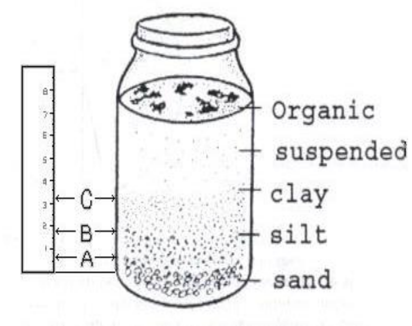

Fig. 8. Soil Jar Test

VII. Hydraulic Conductivity of Tank Bed

Hydraulic conductivity is the efficient movement of water from pore to pore. Hydraulic Conductivity of the Ponpadi and Sengulam tank bed soil was estimated with the falling head Permeameter in the laboratory. Hydraulic conductivity can also determine by infiltrometer [3]. It was observed that in Ponpadi tank the average Hydraulic Conductivity is 24.1 mm/hr at surface, 5.34 mm/hr at 50 cm depth and 24.6 mm/hr at 100 cm depth. Hence Hydraulic Conductivity is high below 100 cm depth when compared with 50 cm depth as shown in fig. 9. In Sengulam tank the average Hydraulic Conductivity is4.2 mm/hr at surface, 18.3 mm/hr below 50 cm depth and 9.1 mm/hr below 100 cm depth. Hence Hydraulic Conductivity is very high below 50 cm at Sengulam tank bed as compared with the surface as shown in fig. 10. In Sengulam tank, rock outcrop is visible at two locations even in 50 cm depth and at eight locations in 100 cm depth.

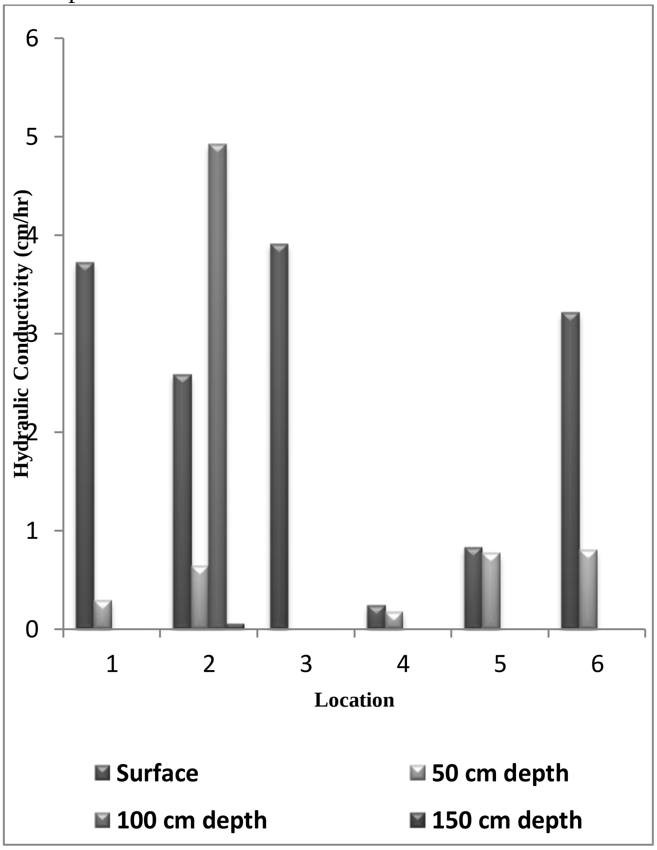

Fig. 9. Hydraulic Conductivity of Ponpadi Tank Bed

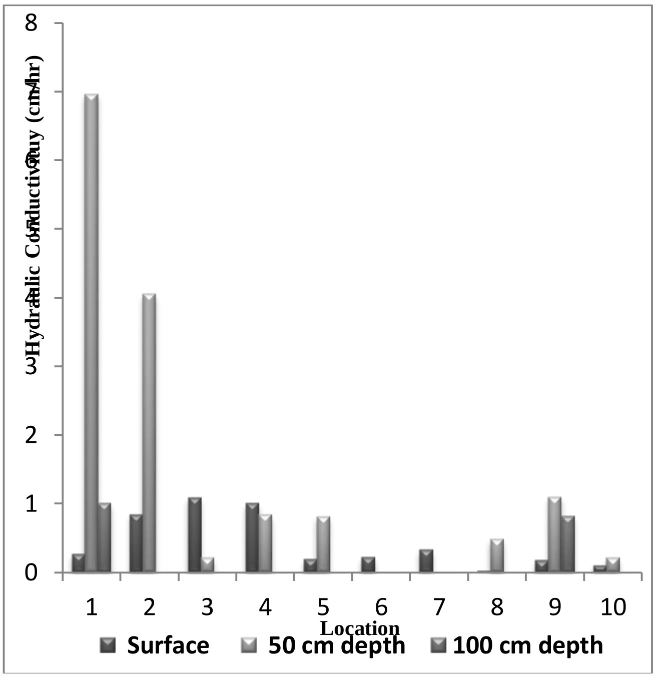

Fig. 10. Hydraulic Conductivity of Sengulam Tank Bed

VIII. Correlation Between Infiltration Rate and Hydraulic Conductivity

In order to establish a relationship between observed infiltration rate and observed hydraulic conductivity for the different soil textures. A graph between observed infiltration rate and observed hydraulic conductivity for different soil texture was plotted as shown in fig. 11.

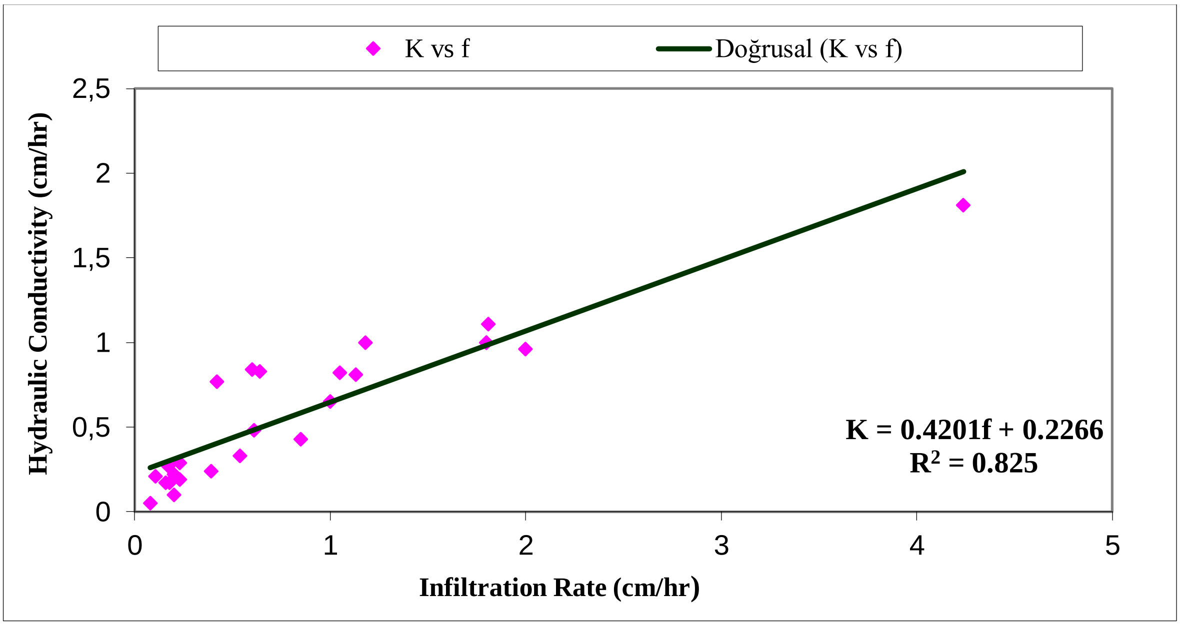

Fig. 11. Relationship between Infiltration Rate and Hydraulic Conductivity

An empirical equation is established for computing infiltration rate if hydraulic conductivity is known which is given in Equation (1)

$$f = \frac{(K - 0.226)}{0.4201} \qquad (1)$$

Where

f : Infiltration Rate (cm/hr)

K : Hydraulic Conductivity(cm/hr)

It was found that the regression coefficient (R^2) was 0.672. Hence sandy soil data was removed and a graph between infiltration rate and hydraulic conductivity was drawn for the remaining soil type. The regression coefficient was increased to 0.825 as shown in fig. 11. Hence it is concluded that above empirical equation is not suitable for sandy soil. However, it is suitable for clay and silt. As most of the tank bed soil is dominated by clay and silt, this equation will be useful to determine the hydraulic conductivity, given the infiltration rate vice versa. From the equation obtained one can easily determine the infiltration rate by knowing the hydraulic conductivity of the sengulam and ponpadi tank bed.

IX. Conclusion

This study will provide a platform to locate the highly permeable zone for partial desilting. The depth to which desilting will be beneficial and economical can be assessed from the strategy adopted in this study. A relation between the infiltration rate and hydraulic conductivity for the selected tank beds has also been established. From the infiltration analysis, hydraulic conductivity studies, and soil texture analysis it was observed that at Ponpadi tank desilting has to be done to a depth of 100 cm, whereas in

Sengulam tank the same has to be done for a depth of 50 cm.

REFERENCES

[1] Ahmad Mousa, Mohamed Mahgoub, and Piotr Wiszowaty, "A Simple Test Method for Rapid Measurement of Fines Content in Soils, "Geotechnical Testing Journal, Vol. 37, No. 2, pp. 177-189, March 2014.
[2] Bruprecht, J. K and N. J. Schofield, "Infiltration Characteristics of a Complex Lateritic Soil Profile, *"Hydrological Processes*, Vol. 7, No. 1, pp. 87-97, January 1993
[3] Van Hoorn, J. W, "Determining hydraulic conductivity with the inversed auger hole and infiltrometer methods," Proceedings of the International Drainage Workshop, In J. Wesseling, ed. pp. 150–154, The Netherlands, 1979.
[4] Riberiro, L and L. M. Nunes, "Permeability Fields Estimation by Conditional Simulation of Geophysical Data,"*Modelling Coping with Uncertainty*, Vol. 20, No. 2, pp. 117 -123, September 1999.
[5] Sharma, S. P and V. C. Baranwal, "Delineation of Groundwater Bearing Fracture Zones in a Hard Rock Area Integrating Very Low Frequency Electromagnetic and Resistivity Data, "Journal of Applied Geophysics, Vol. 57, pp. 155-166, February 2005.
[6] Telis, P. A "Estimation of Infiltration Rates of Saturated Soil at Selected Sites in the Caloosahatchee River Basin," South Western, US Geological Survey, Florida, 2001.

D. Allwin was born in Naduvoorkarai Village, Kanyakumari District, India on 23rdJune 1979. He received his M.E in Hydrology and Water Resources Engineering from College of Engineering, Guindy, Anna University Campus, India and B.E in Civil Engineering from Nanded University, Maharashtra, India. He is now working as an Assistant Professor in Department of Civil Engineering at Noorul Islam University, Kanyakumari, India. His research interests include Groundwater Modelling, Fluid Dynamics and Geophysical Analysis..